Coordinated Interpersonal Timing of Down-Syndrome and Nondelayed Infants with Their Mothers: Evidence for a Buffered Mechanism of Social Interaction

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Abstract. A longitudinal study of four- and nine-month-old infants indicates that they coordinate the timing of their vocal behavior with that of their mothers and vice versa. Maternal interactions of Down-syndrome and nondelayed infants were analyzed and found not to differ with regard to such temporal coordination, indicating that it is independent of level of cognitive functioning. The capacity for coordinated timing is proposed as a mechanism for the facilitation of social interaction. Such coordination parallels temporal matching observed in a variety of species along the phylogenetic scale.

Introduction

Beginning at least with the work of the Gardeners (Gardner and Gardner, 1969; Gardner and Gardner, 1974), researchers have explored the extent to which animals can communicate as do human beings. Our research, on the other hand, has been concerned, in part, with the question of whether human social interaction is made possible, or facilitated by, capacities that are shared with other species and serve the same functions. We report here the results of a longitudinal study of the temporal structure of social communication between nondelayed and Down-syndrome infants in the first year of life and their mothers. The results suggest that coordinated interpersonal timing may serve as a mechanism for the facilitation of social interaction. We conclude that such timing shares features of functionally adaptive social predispositions present in other species.

Conversation is the primary mode of conspecific communication employed by homo-sapiens. Such exchange is an important mechanism serving the organization and maintenance of human society. In this respect, conversational exchange may be viewed as the functional analogue of the bird song and cricket chirp. While the information encoded in a chirp or a song sequence and a conversation may differ radically, the functional consequences of such a signal may be identical: facilitation of mating, bonding between infant and caretaker, guarding against predation, etc.. It is in this functional sense that we are considering a human vocal exchange as equivalent to vocal behaviors observed over a wide range of organisms. There is an extensive body of evidence (Feldstein and Welkowitz, 1987) showing that conversational exchange between adult speakers possesses a complex statistical temporal structure; a structure not entirely subsumed by the syntactic and semantic aspects of such an exchange. Of central interest to our investigation is coordinated interpersonal timing, which refers to an alteration in the temporal patterning of one speaker's behavior as a function of that of the other speaker.

Work with invertebrates, especially insects, and with simple vertebrate models, has begun to delineate a variety of genetic and neurologic factors that are responsible for the temporal organization of social behavior. Thus, for example, investigators (Zerhring *et al.*, 1984; Hamblen *et al.*, 1986) have isolated mutations mapped to a particular region of the X chromosome in *Drosophila*. Mutations on this locus increase, decrease, or destroy completely the temporal pattern of the male fly's mating song. A unique coding sequence that forms a portion of

this locus has recently been identified in several verte-
brates (Schildberger. 1984). Groups of neurons that act
as temporal filters have been identified in crickets
(Schildberger, 1984). These filters are "tuned" to the
temporal properties of the conspecific song. Temporal
filters sensitive to biologically salient stimuli have also
been identified in several species of toads (Rose and Ca-
pranica. 1984). the electric fish, *eigenmannia* (Partridge
and Heiligenberg. 1981), and in rats (Rees and Moller,
1983).

The importance of a capacity for temporal attunement
in terms of the organism's survival is not to be underesti-
mated. Zelick (1986) emphasized the crucial ecological
function served by the temporal patterning of vocaliza-
tion in certain frogs and the electric organ discharge in
the weakly electric fish. Both fish and frogs have adopted
similar strategies of signal oscillator timing to avoid sig-
nal overlap and jamming between conspecifics. Lam-
precht *et al.* (1985) detailed the utility of distance-call
duets in bar-headed geese (*Anser indicus*).

In all of this work, the important variable is the tempo-
ral dimension of the signal. We emphasize that our inves-
tigation is concerned with precisely this dimension and
not with the linguistic process. Obviously, language ex-
hibits a range of phenomena that possess important tem-
poral features. However, our analysis is not concerned
with elucidating the temporal patterns of different lin-
guistic processes such as phonemes, vowel recognition,
or other more "molecular" linguistic features. Our
method of analysis is neutral with respect to the content
of the acoustic signal.

We wished to determine (a) whether human infants
are attuned to the temporal properties of the vocal be-
havior of their adult partners in a dyadic exchange and
(b) the extent to which adults interacting with an infant
are similarly responsive to the temporal characteristics
of the infant's vocal behavior. Finally, we examined the
possibility of a relationship between the capacity for tem-
poral attunement and cognitive development. Given
that the capacity for coordinated timing appears to be
expressed by organisms at various levels of the phyloge-
netic scale, we expected it to be independent of cognitive
functioning. It was this conjecture that dictated our
choice of infants with Down syndrome as one of our two
groups of subjects (Gibson, 1978). We note that other
investigators have utilized the impairment of cognitive

functioning of persons with Down syndrome to disen-
tangle the role played by cognitive functioning in a vari-
ety of human behaviors. Down syndrome offers a valu-
able window into the study of human development. The
pattern of cognitive deficit associated with Down syn-
drome is fairly well understood, and a number of studies
(Ciccheti and Serafica, 1981; Ciccheti and Sroufe, 1976;
Serafica and Ciccheti, 1976; Spiker, 1983) of Down-syn-
drome infants and young children indicates that they
show a pattern of delay rather than deficit in their social
development. Workers such as Ciccheti and his col-
leagues (Ciccheti and Serafica. 1981; Ciccheti and
Sroufe, 1976) have, in fact, used Down syndrome as a
model for studying the interaction of social and cognitive
development. Our choice of infants afflicted with the
syndrome was motivated by the same rationale.

Materials and Methods

Participants

The participants were two groups of caucasian
mother-infant pairs. In one group of nine pairs, the in-
fants were afflicted with Down syndrome (trisomy 21).
Nine pairs of normal, nondelayed infants and their
mothers comprised the other group. The infants with
Down syndrome were recruited from community groups
that provide services for such infants as well as from no-
tices in the media. The nondelayed infants were re-
cruited from notices placed in parent-child newsletters.
All the mothers in the study were native speakers of En-
glish and were highschool graduates. At the initial ses-
sion, each of the mothers was given a brief rating scale
for depression (Radloff, 1977) and another for anxiety
(Zuckerman and Lubin, 1965). None of the mothers
used in the study were found to be clinically anxious
and/or depressed. A medical history was obtained from
each of the mothers concerning her own health, a history
of the pregnancy, and her infant's health. To the best of
our knowledge, none of the infants with Down syndrome
used in this study presented any relevant health prob-
lems.

Procedure

The pairs were seen when the infants were within two
weeks of being four months old, and within two weeks
of being nine months old. On the second occasion, all
the infants were given the Bayley Mental Development
Scale (Bayley, 1969). Each of the mother-infant pairs en-
gaged in a standard face-to-face play procedure for 12
minutes in the Interpersonal Communications Labora-
tory of the University of Maryland Baltimore County. At
the four-month data point, the infant was seated in an
infant seat directly across from its mother at an elevation

such that mother and infant could comfortably achieve eye-contact. At the nine-month point, the infant was seated in an infant chair again oriented in such a way as to make face-to-face interaction comfortable. Also at the nine-month point, the mothers were given a small hand puppet to use as a means of focusing the interaction. This procedure is a standard one and has been used in similar studies (Jasnow and Feldstein, 1986). Two-channel, 12-minute tape recordings were made of each mother-infant interaction. To minimize the spill of one person's voice into the microphone of the other person, contact microphones were used. If during the course of an interaction, the infant became fussy, the taping continued for 30 seconds. If at the end of the 30 seconds the baby was not re-engaged, the taping was stopped until such time as the baby was able to continue.

Vocal analysis

The coding of the vocal behavior was accomplished via the direct input of two audio signals, representing the infant and adult, into a specialized computer system known as the Automated Vocal Transaction Analyzer (AVTA) (Jaffe and Feldstein, 1970). AVTA is a hardware and software system. The hardware component is an analogue-to-digital converter that "listens" to two channels of incoming audio signals to determine whether the signal in each channel is on or off. The audio signals represent the vocal behavior of the two partners. Both sequences of signals are sampled by the A-to-D converter every 250 milliseconds and are stored digitally in the computer in the form of one sequence of four numbers: one signal is on and the other is off, or vice versa; both are on; or both are off. The AVTA system transforms the decimal numbers into the set of dialogic vocal parameters defined below and summarizes them as frequencies, proportions, average durations, and standard deviations for a fixed time interval. The time sampling interval was five seconds because it is approximately equal to the mean plus one standard deviation of each parameter, with the exception of the turn. Inasmuch as the maternal average speaking turns were longer than five seconds, the same criterion yielded 30 seconds as the appropriate sampling unit for the adult turn.

The vocal parameters (Jaffe and Feldstein, 1970; Feldstein and Welkowitz, 1987) generated by the AVTA system are *speaking turns, vocalizations, pauses, switching pauses,* and *simultaneous speech.* Simultaneous speech had too low a rate of occurrence to be included in these analyses. A turn begins the instant a participant starts to vocalize alone and ends immediately prior to the instant that the other participant starts to vocalize alone. A vocalization is a segment of sound uninterrupted by
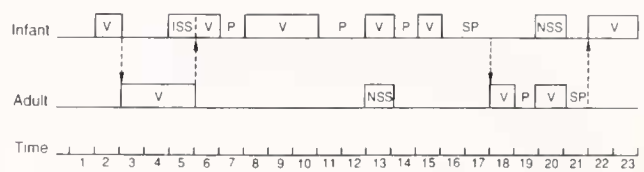

Figure 1. A diagramatic representation of a conversational sequence. The numbered line at the bottom represents time in 250-ms units. V stands for *vocalization,* P for *pause,* and SP for *switching pause* (the silence that occurs immediately prior to a change in the speaking turn). The arrows that point down denote the end of the infant's turns; the arrows that point up denote the end of the adult's turns. ISS and NSS stand for *interruptive* and *noninterruptive simultaneous speech,* respectively. (Adapted from Figure II-2 of Jaffe and Feldstein, 1970).

any discernible silence. A pause is an interval of joint silence that is initiated and terminated by vocalizations of the same participant. A switching pause is a joint silence initiated by the participant who has the turn and terminated by a vocalization of the other participant (Fig. 1).

Statistical analyses

The dyadic time series was divided into five-second[2] segments, or time units, yielding 144 five-second units (over 12 min). A time-series regression (TSR) analysis (Ostrom, 1978) was computed for each parameter to assess the occurrence of coordinated interpersonal timing for each mother-infant pair. The TSR was accomplished by a three-step procedure. The series were first subjected to an ARIMA (SPSSX) modeling procedure for the purpose of "pre-whitening" the data. The ACF subprogram of SPSSX Trends was used to allow for visual and statistical checks to test which model parameters best fit to the data and met the assumptions made by the model. It was determined that the most useful parameter values were 2, 0, 0. Each series was prewhitened separately.

After the selection of the appropriate model, the TSR analyses were computed by the AREG subprogram of SPSSX Trends. It is the temporal coordination that occurs in the current 5- or 30-second sampling interval that was used in this report. In other words, we were concerned with the degree to which changes in one series are reflected by changes in the other series within the same time frame. This relationship is indexed by the standard-

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[2] The five-second time unit was used for the TSR analyses of all the parameters but maternal speaking turns. Average values were computed for each parameter for every five seconds of interaction and for every 30 seconds in the case of maternal turns. Five seconds was chosen because it is approximately equal to the mean + 1 standard deviation for each parameter. Maternal speaking turns had a significantly greater mean value and thus 30 seconds was selected as a more appropriate time unit.

Table I

Summary of Chi square analyses of the results of time-series regressions

Dyad type		T	P	SP	V
Four months					
N: mother-infant	N	10	10	7	10
	R	.52	.14	.07	.21
	χ^2	68.61	35.27	5.78*	126.47
DS: mother-infant	N	8	7	6	8
	R	.61	.15	.11	.21
	χ^2	100.85	28.53	17.48	64.63
Nine months					
N: mother-infant	N	10	10	6	10
	R	.63	.14	.14	.24
	χ^2	79.96	34.89	36.66	89.49
DS: mother-infant	N	10	9	5	9
	R	.89	.09	.07	.16
	χ^2	86.68	17.39	6.81*	30.33

* $P > .05$.

Note. N is the *df* for the Chi square. The *R* represents the average standardized partial regression coefficient. T stands for Turns, P for Pauses, SP for Switching Pauses, V for Vocalizations. The "N" stands for "Nondelayed," the "DS" stands for "Down's syndrome."

ized partial regression coefficient, which is used as a coefficient of coordinated timing.

We wanted two kinds of information. One was whether the group of dyads involving Down-syndrome infants and the group of dyads involving nondelayed infants each engaged in coordinated interpersonal timing. This information was provided by a meta-analytic approach in which standard normal deviate scores are obtained for the probability values associated with the regression coefficients. Each of these standard scores is squared to yield a Chi square with one degree of freedom. The Chi squares are then summed for each group of dyads to provide a Chi square test (with *df* equal to the number of Chi squares in the sum) of whether the regression coefficients in each group were significantly different from zero. Another was whether the two groups differed in terms of the extent with which they engaged in coordinated timing. Differences between the two groups of mother-infant pairs (nondelayed and delayed) and between the two age groups (four and nine months) were assessed by a split-plot analysis of variance.

Results

The Chi square analyses of the results indicate that mutual coordination occurred for all but one of the temporal parameters, at both 4 and 9 months, regardless of diagnosis (Table I).

Given that the meta-analytic results demonstrate that

temporal coordination occurred across all but one of the vocal behaviors, or parameters, the question is whether the two groups can be discriminated on the basis of their magnitudes of coordination. The analysis of variance of the pauses, switching pauses, and vocalizations yielded a significant main effect for diagnosis ($F[1, 17] = 4.34, P = .05, \epsilon = .40$), indicating that the dyads with the delayed infants seemed to engage in less coordination than their nondelayed counterparts. However, the occurrence of a significant interaction of diagnosis by age ($F[1, 17] = 4.34, P = .05, \epsilon = .40$) indicates that the apparent general difference between the two groups is primarily attributable to a significantly lower degree of coordination of the Down-syndrome dyads at four months of age. By the time the delayed infants reach nine months of age, their average degree of coordination with their mothers is similar to that of the nondelayed dyads (Fig. 2).

The results of the analysis of speaking turns (done separately because of the larger sampling interval) provide no evidence of a difference in degree of coordination between the dyads with the delayed infants and those with the nondelayed infants ($F[1, 17] = 0.00, P = .959$). Nor did the magnitude of coordination of either group of dyads change markedly with time ($F[1, 17] = 0.70, P = .415$).

Discussion

The results offer support for the hypothesis that infants and their mothers coordinate the temporal organization of their vocal behavior both when the infants are four
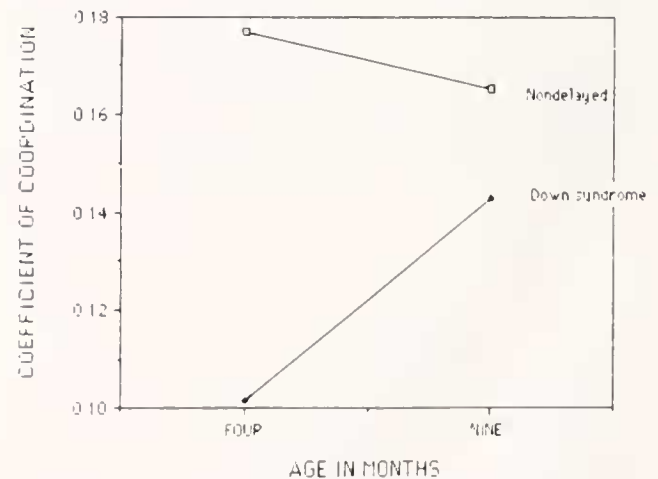

Figure 2. The interaction of the diagnosis by age, indicating that whereas the degree of coordinated interpersonal timing of the dyads with nondelayed infant is similar when the infants are four and nine months of age, that of the dyads with Down's syndrome infant increases significantly from four to nine months.

months and nine months old. They demonstrate that the temporal phenomenon found to characterize adult conversation (Partridge and Heiligenberg, 1981; Feldstein and Welkowitz, 1987) is present in adult-infant interactions from as early as four months of age and that the results are true not only for nondelayed infants, but also for infants afflicted with Down syndrome. Thus the study, having used a group about whose cognitive impairment there can be no doubt, represents a strong test of the proposition that coordinated interpersonal timing is independent of cognitive ability.

Note, however, that although coordination appears to be a general phenomenon detected in both groups at both ages, the two groups could be discriminated on the basis of the lower degree of coordination exhibited by the Down-syndrome infants and their mothers at four months of age. This finding of lower coordination at four months increasing, by nine months, to a level similar to that of the nondelayed dyads, is consistent with the findings from a wide array of studies about the social behavior of Down-syndrome infants. These studies (Ciccheti and Sroufe, 1976; Serafica and Ciccheti, 1976; Ciccheti and Serafica, 1981; Spiker, 1983) have shown that dysfunctional aspects of social behavior of Down-syndrome infants and young children are related to deviations in rate of development and not to deficits in development.

The capacity to process and respond to the temporal patterning of human vocalizations may enable the infant to select and "lock onto" a biologically important environmental stimulus. That this capacity is present in infants suffering from severe cognitive impairment suggests that it may be buffered against insults to the organism. In other words, it may be that the capacity functions to make social interaction possible. The underlying neuromechanisms responsible for such temporal sensitivity are not known. Workers such as Rose (1986) have observed that many different types of organisms employ the same set of neurons in the midbrain for processing certain varieties of temporal information. Rose speculated that similar mechanisms may be operative in human beings. Zelick (1986) pointed out that the behavior strategies adopted by certain frogs and the weakly electric fish to avoid signal jamming are quite similar, and suggested that common neuromechanisms may be responsible for the common behavioral strategy. Whether the mechanisms underlying the behaviors described in this report are similar to those that operate in nonhuman organisms remains open to investigation.

There is no doubt that the temporal patterning of social interaction is a fundamental aspect of behavior in any given ecological setting. Marler and Terrace (1984) noted that "The mechanisms that underlie imprinting and song learning cannot be understood without first ac-

knowledging the pervasive role of unlearned, functionally adaptive predispositions to associate particular classes of stimuli" (p. 5). We conjecture that the responsivity to the temporal patterning of vocal behavior demonstrated by the findings presented here is an instance of such a functionally adaptive predisposition in human beings.

Acknowledgments

Literature Cited

Bayley, N. 1969. *Bayley Scales of Infant Development.* Psychological Corp.

Ciccheti, D., and F. Serafica. 1981. Interplay among behavioral systems: illustrations for the study of attachment, affiliation and wariness in young children with Down's syndrome. *Dev. Psychol.* 17: 36–49.

Ciccheti, D., and A. Sroufe. 1976. The relationship between cognitive development in Down's syndrome infants. *Child Dev.* 47: 920–929.

Feldstein, S., and J. Welkowitz. 1987. A chronography of conversation: in defense of an objective approach. Pp. 435–499 in *Nonverbal Behavior and Communication*, A. W. Siegman and S. Feldstein, eds. Erlbaum, Hillsdale, NJ.

Gardner, R. A., and B. T. Gardner. 1969. Teaching sign language to a chimpanzee. *Science* 165: 664–672.

Gardner, B. T., and R. A. Gardner. 1974. Two-way communication with an infant chimpanzee. Pp. 171–184 in *Behavior of Nonhuman Primates*, Vol. 4, A. M. Schrier et al., eds. Academic, New York.

Gibson, D. 1978. *Down's Syndrome: The Psychology of Mongolism.* Cambridge University Press, New York.

Hamblen, H., W. A. Zehring, C. P. Kyriacou, P. Reddy, Q. Yu, D. A. Wheeler, L. J. Zwiebel, R. J. Konopka, M. Rosbash, and J. C. Hall. 1986. Germ-line transformation involving DNA from the period locus in *Drosophila melangaster*: overlapping neural fragments that restore circadian and ultradian rhythmicity to per° and per⁻ mutants. *J. Neurogen.* 3: 249–291.

Jaffe, J., and S. Feldstein. 1970. *Rhythms of Dialogue.* Academic, New York.

Jasnow, M. D., and S. Feldstein. 1986. Adult-like temporal characteristics of mother-infant vocal interactions. *Child Dev.* 57: 754–761.

Lamprecht, J., A. Kaiser, A. Peters, and C. Kirchgessner. 1985. Distance call duets in bar-headed geese (*Anser indicus*): Cooperation through visual relief of the partner? *Z. Tierpsychol.* 70: 211–218.

Marler, P., and H. Terrace, eds. 1984. *Dahlem Konferanzen* Springer-Verlag, Berlin.

Ostrom, C. W. 1978. *Time Series Analysis: Regression Techniques.* Sage, Beverly Hills, CA.

Partridge, B. L., and W. Heiligenberg. 1981. Pp. 309–319 in *Ad-*

vances in Vertebrate Neuroethology, J. P. Ewert *et al.*, eds. Plenum, New York.

Radloff, L. 1977. The CES D Scale: A self-report depression scale for research in the general population. *Appl. Psychol. Measure* **1**: 385–401.

Rees, A., and A. R. Moller. 1983. Responses of neurons in the inferior colliculus of the rat to AM and FM tones. *Hear. Res.* **10**: 301–330.

Rose, G. 1986. A temporal processing mechanism for all species. *Brain Behav. Evol.* **28**: 134–144

Rose, G., and R. Capranica. 1984. Accessing amplitude-modulated sounds by the auditory midbrain of two species of toads: matched temporal filters. *J. Comp. Physiol.* **154**: 211–219.

Schildberger, K. 1984. Temporal selectivity of auditory neurons in the cricket. *J. Comp. Physiol.* **155**: 171–185.

Serafica, F., and D. Ciccheti. 1976. Down's syndrome children in a strange situation: attachment and exploration behaviors. *Merrill-Palmer Q.* **22**: 137–150.

Shin, H. S., T. A. Bargiello, B. T. Clark, F. R. Jackson, and M. W. Young. 1985. An unusual coding sequence from a *Drosophila* clock gene is conserved in vertebrates (Letter). *Nature* **317**: 445.

Spiker, D. 1983. Early intervention for young children with Down's syndrome: new directions for enhancing parent child synchrony. In *Down's Syndrome: Advances in Biomedicine and the Behavioral Sciences*. S. Peuschel and J. Rynders, eds. The Ware Press, Cambridge, MA.

Zerhring, W. A., D. A. Wheeler, P. Reddy, R. J. Konopka, C. P. Kyriacou, M. Rosbash, and J. C. Hall. 1984. P-element transformation of period locus DNA restores rhythmicity to mutant, arhythmic *Drosophila melangaster. Cell* **39**: 369–376.

Zelick, R. 1986. Jamming avoidance in electric fish and frogs: strategies of signal oscillator timing. *Brain Behav. Evol.* **28**: 60–69.

Zuckerman, M., and B. Lubin. 1965. *Manual for the MAACL.* Educational and Industrial Testing Service, San Diego, CA.